IONOSPHERIC RESEARCH

Fifteenth Quarterly Progress Report

1 April 1967 to 30 June 1967

Contract No. DA 36-039-AMC-03703(E)
File No. 39606-PM-60-91-91-(8750)
DA Project No. 3A99-20-001-04

by
H. D. WEBB

ELECTRICAL ENGINEERING RESEARCH LABORATORY
ENGINEERING EXPERIMENT STATION
UNIVERSITY OF ILLINOIS
URBANA, ILLINOIS

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IONOSPHERIC RESEARCH

Report No. 15

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OBJECT OF THE PROJECT:

(1) To continue the work carried out under Contract SC85173 by receiving signals by reflection from the moon and measuring the Faraday Rotation; (2) to use the data to calculate the electron content of the ionosphere above the earth; (3) to study the diurnal, seasonal and irregular changes in electron content; (4) to correlate irregular changes in electron content with other natural phenomena; and (5) to study the reflecting surface of the moon.

Report Prepared by

H. D. Webb, Professor

Sponsored by

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Electrical Engineering Research Laboratory
University of Illinois
Urbana, Illinois

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

1. PURPOSE

The purpose of this contract is to continue the work that was carried out under Contract SC85173. Signals are received by reflection from the moon for the purpose of studying the ionosphere above the earth and for studying the nature of the reflecting surfaces on the moon. The reception, recording and processing of the signals will be designated Task A. The use of the recorded signals and processed data for studying the ionosphere above the earth will be designated Task B. The use of the signals for studying the surface of the moon will be designated Task C. Other research that may be carried out, which will be mutually agreeable between USAEC and University of Illinois personnel, will be designated Task D.

The phases of the various tasks, as revised in Quarterly Progress Report No. 14, are indicated below.

Task A. Receiving and Processing Moon-Reflected Signals

- Phase 1. Reception of Moon-Reflected Signals
- Phase 2. Processing the Data to Obtain Electron Content
- Phase 3. Study of Methods for Automatic Operation of the Receiving Station

Task B. Analysis of Electron Content Data

- Phase 1. Resolution of the n x 180° Ambiguity and Study of Methods for Resolving the Ambiguity
- Phase 2. Preparation of an Atlas of Faraday Rotation Electron Content Data
- Phase 3. Other Studies of the Data

Task C. Autocorrelation Analysis

Task D. Other Research

2. ABSTRACT

Moon reflected signals were received at 150.6 MHz and 413.25 MHz on 35 days for 330 and 64 hours of operation, respectively. The operational times are summarized in tabular and in graphical form.

Solid state servo amplifiers using SCR's are in operation for both azimuthal and elevation control. Circuit diagrams and brief descriptions of operation are given.

Uncertainties in some of the 413.25 MHz data for 1966 are being resolved using ionograms. Some topside to bottomside ratios for 1965 data have been calculated.

Signals from ATS-1 were recorded from 1120 CST May 21 to 0210 CST May 28. This period included several major solar flares and a severe magnetic storm May 25-27. The electron content data for May 21 and May 23 are presented. At the time of the flare on May 21 there was an increase of 1.6×10^{16} electrons per square meter in 5 minutes. On May 23, at the time of the flare there was an increase of 3.2×10^{16} electrons per square meter in 15 minutes.

Data showing unusual effects during the magnetic storm May 25 are withheld, pending further study.

3. PUBLICATIONS, LECTURES, REPORTS AND CONFERENCES

3.1 Publications

The following theses for the M.S. degree in Electrical Engineering have been completed under this contract.

Hugh W. Richardson, "Analysis of 440 mc Radiation from the Sun During the Eclipse of July 20, 1963."

William H. Berger, Jr., "Study of Traveling Disturbances in the Earth's Ionosphere."

Arthur H. Hardy, Jr., "Evaluation of Methods Used to Resolve the n Π Ambiguity in the Faraday Rotation of Signals Reflected from the Moon."

Fredrick P. Ziolkowski, "A Model for the Correlation of Ionospheric Electron Content and Geomagnetic Irregularities."

Josef W. Rokus, "Effects of Solar Flares on the Electron Content of the Earth's Ionosphere."

Henry Camargo Roncancio, "The Electron and Ion Temperature in the F-Region of the Ionosphere."

John L. Geisinger, "A Conical Log-Spiral Antenna Design for Use at 150 Megacycles."

David H. Cowling, "Automation of the Moon Reflection Station at Danville."

3.2 Lectures

None

3.3 Reports

First Quarterly Progress Report for the period 12 September 1963 to 11 December 1963.

Second Quarterly Progress Report for the period 12 December 1963 to 11 March 1964.

Third Quarterly Progress Report for the period 12 March 1964 to 11 June 1964.

Fourth Quarterly Progress Report for the period 12 June 1964 to 30 September 1964.

Fifth Quarterly Progress Report for the period 1 October 1964 to 31 December 1964.

Sixth Quarterly Progress Report for the period 1 January 1965 to 31 March 1965.

Seventh Quarterly Progress Report for the period 1 April 1965 to 30 June 1965.

Eighth Quarterly Progress Report for the period 1 July 1965 to 30 September 1965.

Ninth Quarterly Progress Report for the period 1 October 1965 to 31 December 1965.

Tenth Quarterly Progress Report for the period 1 January 1966 to 31 March 1966.

Eleventh Quarterly Progress Report for the period 1 April 1966 to 30 June 1966.

Twelfth Quarterly Progress Report for the period 1 July 1966 to 30 September 1966.

Thirteenth Quarterly Progress Report for the period 1 October 1966 to 31 December 1966.

Fourteenth Quarterly Progress Report for the period 1 January 1967 to 31 March 1967.

3.4 Conferences

During the period May 23-26, 1967, Dr. H. D. Webb attended the meeting of URSI at the University of Ottawa, Ottawa, Ontario, Canada.

Dr. F. B. Daniels visited the University of Illinois June 13-15, 1967, to discuss the publication of a paper dealing with nighttime electron content and to discuss various items with regard to future work using lunar reflections.

4. FACTUAL DATA

4.1 Task A. Faraday Rotation Studies

4.1.1 Phase 1. Reception of Moon-Reflected Signals

Moon reflected signals were received at 150.6 MHz on 35 days for approximately 330 hours of usable recorded signals. In addition, signals at 413.25 MHz were received on 35 days for approximately 64 hours of operation. Summaries of the times of observation at 150.6 MHz and 413.25 MHz are given in Tables I and II, respectively.

Figure 1 shows a graphical summary of the times of observation for the period January 1 through June 30, 1967. The graphical summary does not indicate off periods between the beginning and end of the run. For many kinds of study of the data short periods of no reception are not particularly bothersome since the plotted curves can be smoothed across the gap. There are times for which absence of data can lead to uncertainties. For example, on June 5 no signals were received from 0822 to 1233 due to a power failure in New Jersey. When the signals at 150.6 MHz returned at 1233 there is no way of knowing from this data alone how the electron content curve following 1233 fits the curve for data obtained prior to 0822.

There are several notes at the end of Table I. These notes indicate times greater than 20 minutes during which no signals were received. If the periods of no received signal occurred during times when the station was unattended, we cannot state the reason for no signals, i.e., whether the fault was at the transmitter or at the receiving station. In a few instances, as for Note g, the reason for no received signals is indicated.

TABLE I

Calendar of Moon Reflection Observations

for Apri. 1 through June 30, 1967, at 150.6 MHz.

Date	Starting Time CST	Closing Time CST	Time Duration of Observation Hours	Minutes	A_{F_r} and Flares	Notes
April 3	0510	1000	3	53	3	a
4	0601	1130	5	29	11	
5	0458	1230	6	53	10	b
6	0534	1330	7	56	10	
7	0603	1344	6	43	10	c
8	0608	1532	9	24	4	
10	1130	1536	3	23	6	d
11	0852	1741	8	49	2-S2B	
12	0727	1910	11	43	4	
13	0906	2030	11	24	2	
14	0940	2130	10	00	2	e
15	0929	2230	13	01	3	
May 3	0333	1030	6	57	40	
4	0538	1200	6	22	9	
5	0406	1300	8	54	10	
8	0527	1600	10	33	4	
9	0542	1640	10	58	5	f
10	0602	1815	12	13	7	
11	0630	1935	13	05	10	
12	0700	1518	8	18	13	
13	0818	2130	13	12	16	
15	0959	2200	12	01	5	
16	1118	2200	10	42	8	
June 5	0330	1500	6	30	27S-2B	g
6	0430	1600	11	30	49	
7	0505	1700	11	55	18	h
8	0549	1200	6	11	12	i
9	0603	1859	12	56	17	j
10	0702	2003	12	18	8	k
12	0927	2059	11	32	5	
13	1032	2159	11	27	6	
14	1134	2158	9	34	20	l
15	1302	2159	8	57	10	
June 16	1359	2200	8	01	6	
17	1456	2200	7	04	10	

Totals: 35 days, 329 hours, 48 minutes.

Notes:

a. No recorded signals 0523 to 0543 and 0851 to 0928 for a total of 57 minutes.

b. No recorded signals from 0742 to 0821, for a total of 39 minutes.

c. No recorded signals from 0812 to 0835 and 0908 to 0943 for a total of 58 minutes.

d. No recorded signals from 1158 to 1241 for a total of 43 minutes.

e. No recorded signals from 1532 to 1603 and 1812 to 1931 for a total of one hour and 50 minutes.

f. There was a partial eclipse of the sun May 9. At the time of maximum eclipse about 15% of the solar disk was obscured at Danville.

g. No signal was received between 0414 and 0503 due to antenna feed trouble at Danville. No signal was received from 0822 to 1233 due to power failure at Belmar. The total off time was five hours.

h. Signal was poor until 0530.

i. The observation was scheduled to continue until 1800 but was not usable after 1200 due to lightning.

j. Lightning from 1640 to 1806.

k. No signal received between 1640 and 1723 for a total of 43 minutes.

l. No signal received from 1944 to 2034 for a total of 50 minutes.

TABLE II

Calendar of Moon Reflection Observations
for April 1 through June 30, 1967, for 413.25 MHz.

Date	Starting Time CST	Closing Time CST	Time Duration of Observation Hours	Minutes	Notes
April 3	0800	1000	2		
4	0833	1001	1	28	
5	0759	1001	2	02	
6	0800	1000	2		
7	0805	1000	1	55	
8	0802	1000	1	58	
10	1241	1430	1	49	
11	0907	1005	1	58	
12	0812	1001	1	49	
13	0813	1000	1	47	
14	1327	1530	2	03	
15	0927	1130	2	03	
May 3	0657	0900	2	03	
4	0700	0900	2		
5	0658	0900	2	02	
May 8	0700	0902	2	02	
9	0700	0901	2	01	
10	0703	0901	1	58	
11	0702	0900	1	58	
12	0700	0900	2		
13	0800	1000	2		
15	1159	1400	2	01	
16	1159	1400	2	01	
June 5	0658	0822	1	24	a
6	0704	0900	1	56	
7	0720	0900	1	40	
8	0830	0904		34	b
9	0659	0859	2		
10	0706	0902	1	56	
12	0933	1131	1	58	
13	1123	1234	1	11	c
14	1135	1331	1	56	
15	1305	1448	1	43	
16	1435	1600	1	25	
17	1505	1701	1	56	

Totals: 35 days, 64 hours, 37 minutes.

Notes:

a. Power failure at Belmar at 0822.

b. Signal very poor on this date, due to local conditions.

c. Receiver trouble at Danville until 1123.

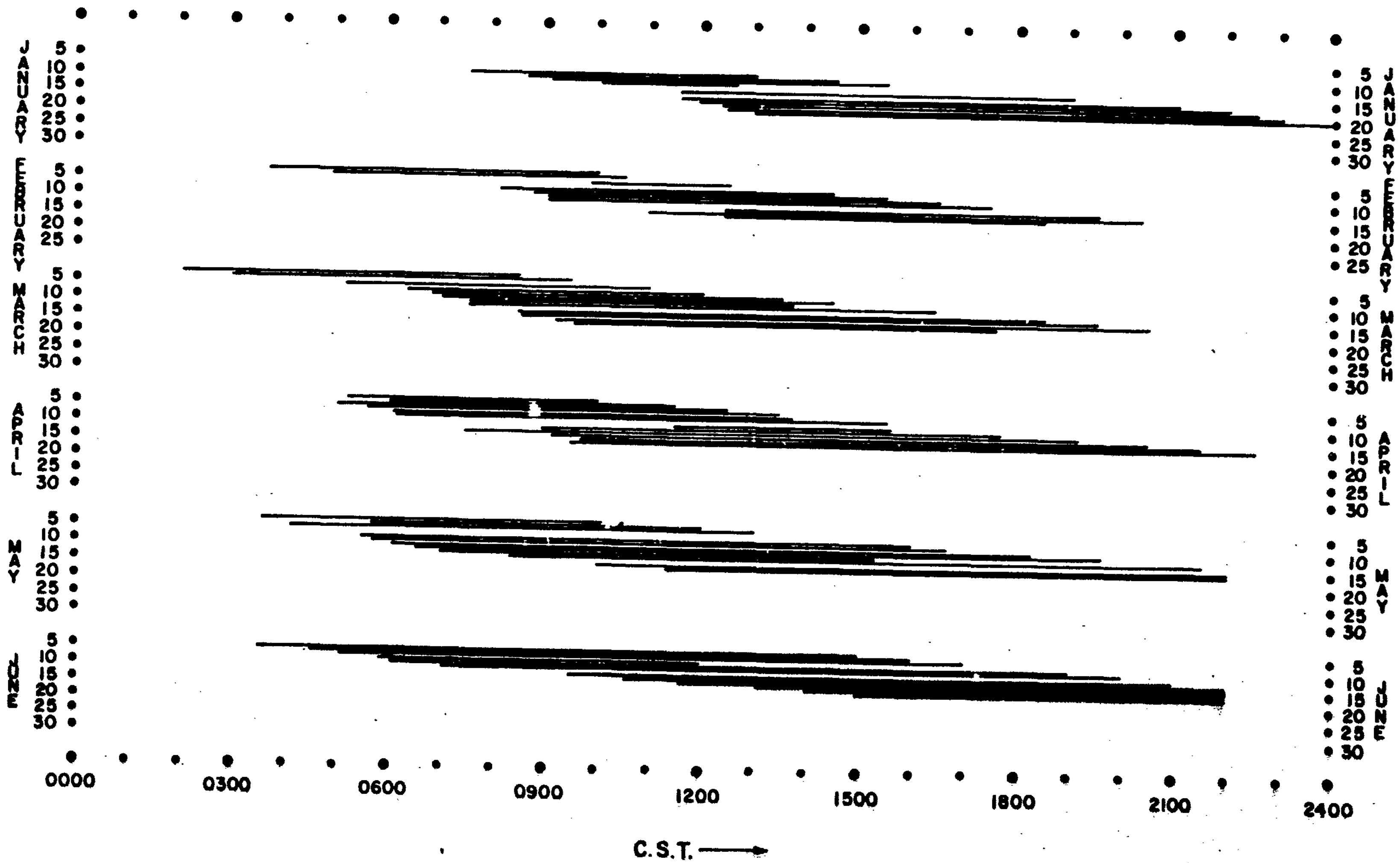

Figure 1. Periods of reception of moon-reflected signals at 150.6 MHz for January through June 1967.

The receiving station was attended for the period during which the 413.25 MHz signals were received. The times of reception of the 413.25 MHz signals are given in Table II.

Importance 2 B solar flares were reported on April 11 and June 5.

Magnetic storm No. 121 started at 1907 UT on May 1 and ended at 0300 UT on May 4. The storm A index was 40. The observations on May 3 were made during this magnetic storm.

Magnetic storm No. 125 started at 1800 UT June 5 and ended at 0700 UT June 6. The A index was 60. Magnetic storm No. 126 began at 1800 UT June 6 and continued until 0800 UT June 7. The A index was 27. These storms were in progress during part of our observations.

The processing of the lunar data for the dates of the above magnetic storms and flares has not been completed. Any correlation of the data with the above activity cannot be discussed at this time.

There was some very severe solar activity and magnetic activity during the period May 21-28. There were no lunar observations during this time. Signals from ATS were received during this period. These results will be discussed under Task D, section 4.4.

4.1.2. Phase 2. Processing the Data to Obtain Electron Content

The calculations of corrected Faraday rotation angle and electron content have been completed for January 1967. The strip charts have been read out for all of the April observations and part of the May observations. The delay in getting the data processing up to date has been brought about by the necessity of using ionograms for verifying the resolution of the n x 180° ambiguity in some of the 1966 data.

4.1.3. Phase 3. Study of Methods for Automatic Operation of the Receiving Station.

David Cowling

After the development of the Mark I Solid State Servo Amplifier described in Quarterly Progress Report No. 13, more and more trouble was encountered with commutation failures of the driving SCRs.

When a commutation failure does occur in the driving circuit, a fuse blows to protect the driving SCRs. Once this fuse has blown the servo amplifier is inoperative.

If someone is present at the Danville site when the fuse blows, he can replace it. However, if no one is there the antenna will stop tracking the moon and data will be missed.

Changing values in a feed back loop associated with the driving circuit and other changes in the drive did not seem to improve the situation markedly.

In March an elevation motor bearing burned out. We felt that this might have been contributed to by the continuous searching associated with the magnetic amplifier in use. On this basis it was decided to replace the elevation magnetic servo amplifier with a solid state device. However, because of the commutation difficulties experienced in the original version (Mark I), it was decided to extend the development of this amplifier before constructing a second one.

The design used for the final drive is shown in Figure 2[1,2] which is the same as Figure 3.3 in Quarterly Progress Report No. 13. In operation either SCR-1 or SCR-2 is triggered every half cycle. This causes either Bridge-1 or Bridge-2 to present a very low impedance path for current while the bridge associated with the SCR not being triggered looks like a very high impedance path. Therefore, when SCR-1

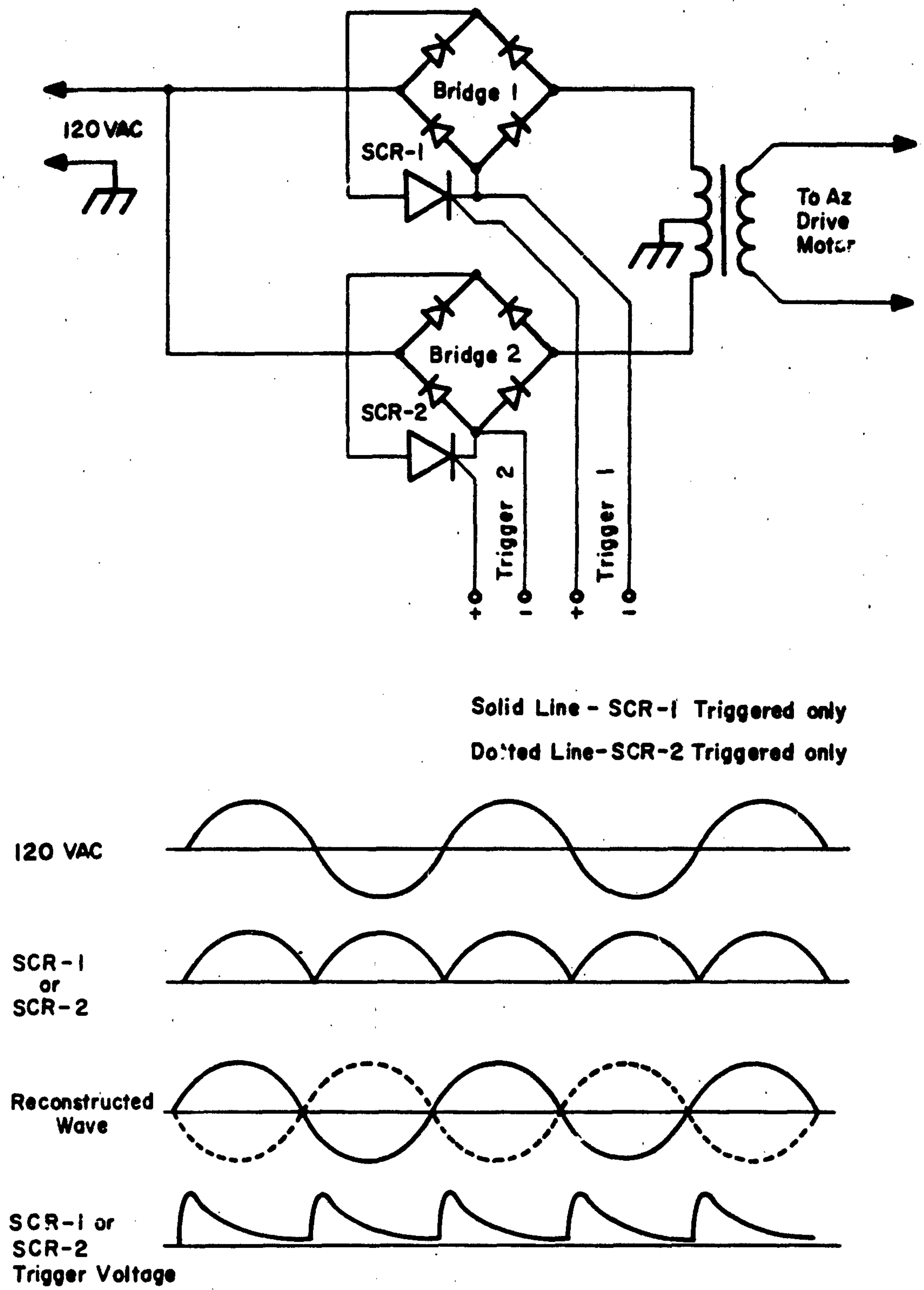

Figure 2. Block diagram of servo drive for azimuth control.

is being triggered, the output of the driving transformer will be of one phase and when SCR-2 is being triggered, this output will be phase shifted by 180°. This is the type of phase shift required to reverse the antenna positioning motor. A full wave rectified sine wave of less than 10 volts amplitude is used to trigger the SCRs.

Figure 3 shows a block diagram of the completed Mark II and Mark III versions. The error voltage returning from the antenna Synchro generator is limited by the diode limiter, amplified and fed into a phase discriminator. Here its phase is compared to that of the 60 cps AC line. The output of the phase discriminator is a DC voltage. This voltage is applied to an emitter follower and the output of this in turn is used to turn on or off two DC amplifiers. These amplifiers are arranged so that they are both normally in a cutoff condition, but, depending on the DC current applied to them from the DC emitter follower, either one or the other will saturate on a relatively small signal. These DC amplifiers control two bridges by saturating transistors across these bridges. In Figure 3 the bridge and transistor combinations are shown as trigger switch #1 or #2.

The bridge that is conducting supplies a 60 cps sine wave to a full wave rectifying bridge where it is rectified and fed to the associated SCR to trigger it. The rest of the operation is as described previously.

The trigger switch biasing control determines how close to saturation the two DC amplifiers must be before they turn on their respective transistor and bridge combination (trigger switch #1 or #2). This in turn is related to the amount of input error voltage which is proportional to actual antenna error (for small angles). Too low a setting will make the

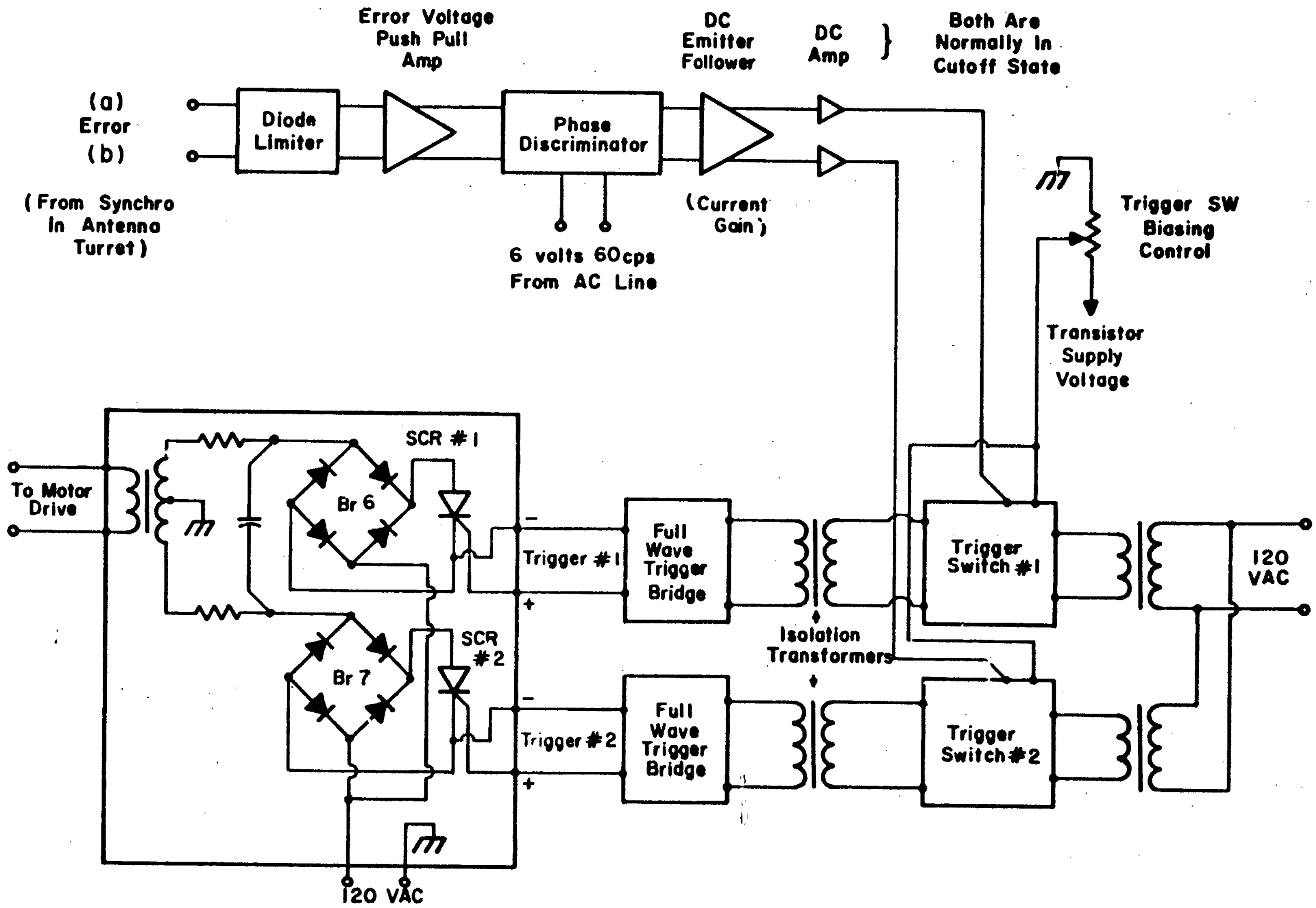

Figure 3. Block diagram of Mark II and Mark III servo amplifiers.

antenna hunt and too high a setting will give excessive antenna position error.

The Mark II version was constructed and applied to control the azimuth positioning motor in place of the Mark I mentioned in the 13th quarterly progress report. It seemed to work well, so a Mark III version was constructed and installed in place of the magnetic amplifier associated with the elevation positioning motor. Both amplifiers have been in operation since April 1967. A maladjusted trigger switch biasing control caused trouble in the Mark III version right after installation. This was corrected and to date no other mechanical or electrical difficulties have been encountered.

Operationally, the amplifier has demonstrated only one bad feature. When the antenna is swung to a fixed position through an angle of larger than about ten degrees, it will hunt about this fixed position. The damping of the hunting is critical and depends upon the setting of the trigger switch biasing control. This fault could be corrected at some future time by the installation of a rate control which samples the back EMF from the antenna positioning motor.

Once this hunting has damped out, it will not recur during the tracking of the moon. In the course of normal operation at Danville no problem should arise, for someone has to go to Danville between runs to set the coordinate resolver for the next day's run. In the process the antenna is moved to its starting coordinates. Therefore, when the station turns itself on, no problem is expected to occur.

Figure 4 shows the schematic wiring diagram for the Mark II and Mark III servo amplifiers. Figure 5 shows the surface wiring diagram for the Mark II and Mark III servo amplifiers. This includes a 25 volt

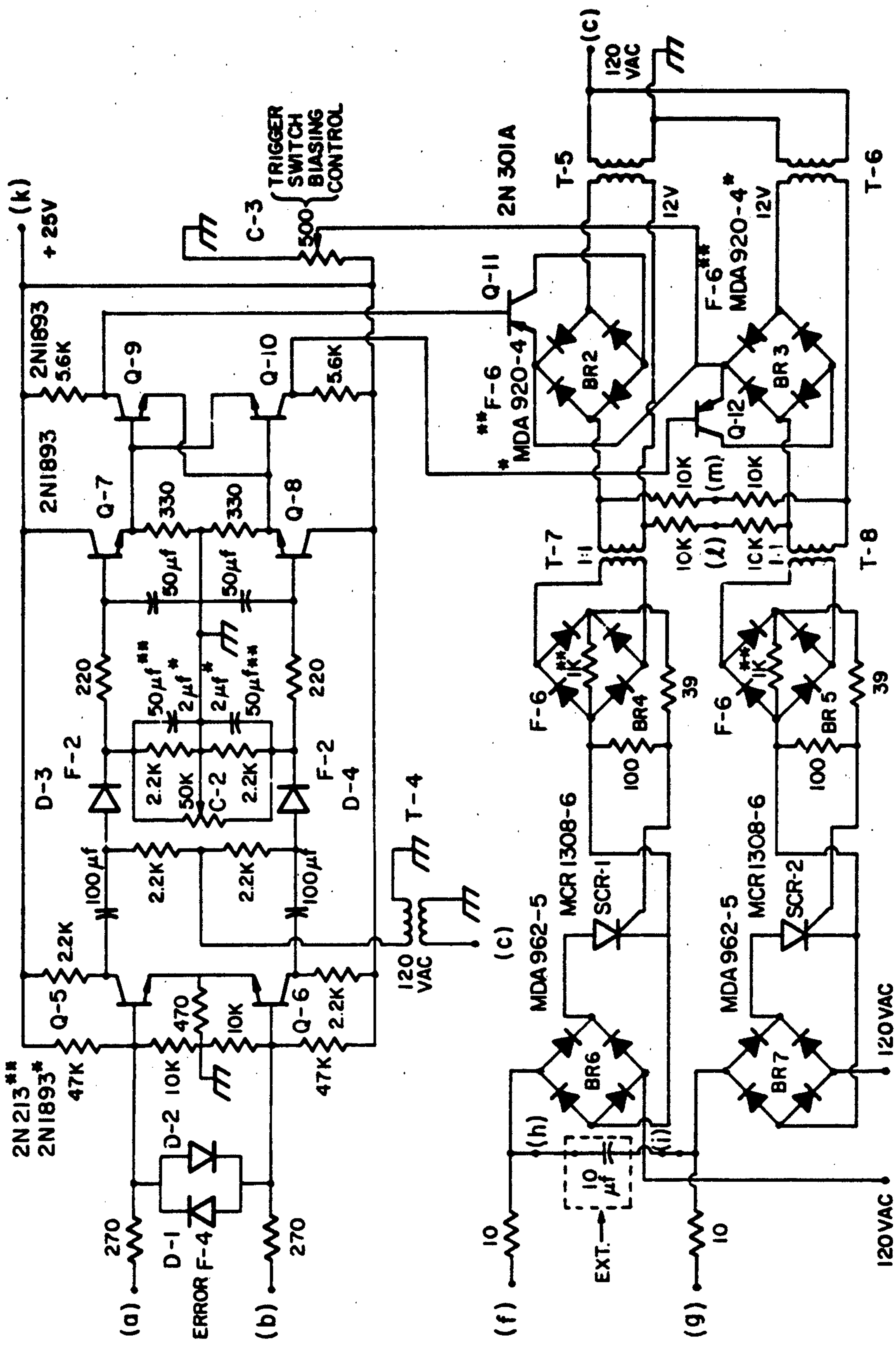

Figure 4. Schematic diagram for the Mark II and Mark III servo amplifier drives

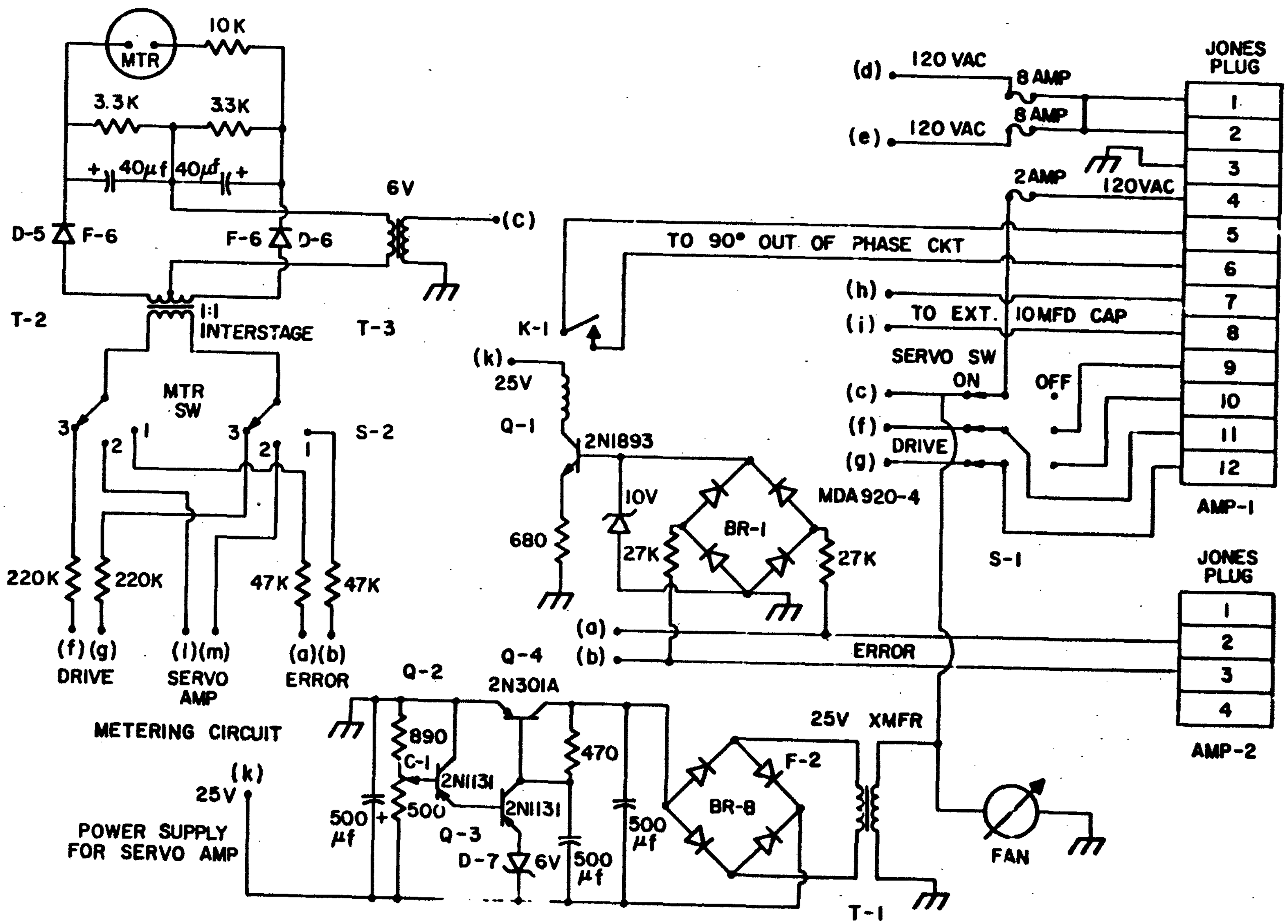

Figure 5. Surface wiring diagram for the Mark II and III servo amplifiers.

DC power supply, a circuit to close a relay to place, effectively, a larger voltage on the 90° out of phase circuit when the error is large, and the metering circuit.

4.2. Task B. Analysis of Electron Content Data

4.2.1. Phase 1. Resolution of the n x 180° Ambiguity

Donald Jeanblanc

Apparent heights for several plasma frequencies have been read from Ft. Monmouth ionograms and local ionograms for October 1965, and from local ionograms for several days in 1966. These data are to be used in a computer program to compute true heights of the f_{oF_2}, the integrated electron content up to f_{oF_2} and the topside to bottomside ratio, r. Resolved electron content data from the lunar Faraday rotation experiment are used in addition to the ionogram data to get the ratio r.

The computer programs are being modified so that slab thickness and electron and ion temperatures can also be calculated.

The program has been run to obtain the ratios for several datum points for October 1965.

4.2.2. Phase 2. Preparation of an Atlas of Faraday Rotation and Electron Content Data.

The completion of the plots of Faraday rotation and electron content versus CST and LTASP has been delayed for several reasons, one being the lack of hourly employees due to graduation, completion of semester examinations, and taking on summer employment in other cities.

It was pointed out in the Fourteenth Quarterly Progress Report that the n x 180° ambiguity for the 150.6 MHz Faraday rotation data has not been resolved for all of the 1966 data because there are uncertainties, or ambiguities, in some of the 413.25 MHz data. It has been decided to use ionograms data to integrate the electron density up to the height of the F_2 max, or f_{oF_2}.

A step of 180° at 413.25 MHz corresponds to a step of about 13×10^{16} to 26×10^{16} electrons per square meter column, depending upon the value of $\overline{M}$. Since this step is large, a highly accurate procedure for calculating integrated electron content up to f_{oF_2} is not required. In trying to think of a quick, approximate method, the following procedure was devised, which is explained with the aid of Figure 6.

The area of the parabolic section BC shown in Figure 6a is given by area = $\frac{2}{3}\,\overline{AC} \times \overline{AB}$. An electron density profile is indicated in Figure 6b. If the part of the electron density profile between heights h_1 and h_2 is parabolic in shape, the area of the section $h_1h_2(B)$ is $\frac{2}{3}$ $(h_2-h_1) \times \overline{h_2(B)}$. But $\overline{h_2(B)} = N$, the electron density at f_{oF_2}, and $N = \frac{(f_{oF_2})^2}{80.6}$ electrons per cubic meter. If this number is multiplied by $\frac{2}{3}$ (h_2-h_1) in meters the integrated electron content in electrons per square meter column is obtained. If this number is multiplied by $(1 + r)$, where r is the top to bottom electron content ratio as given by Hardy (Sixth Quarterly Progress Report, p. 55), it will give the total integrated electron content.

This simple procedure will not give an accurate value for the electron content for several reasons, among which are: (1) the lower part of the electron density profile is not parabolic in shape, as indicated by Figure 6c; (2) one cannot accurately read the height of f_{oF_2} from the ionogram; and (3) the ratio r is not accurately known as a function of

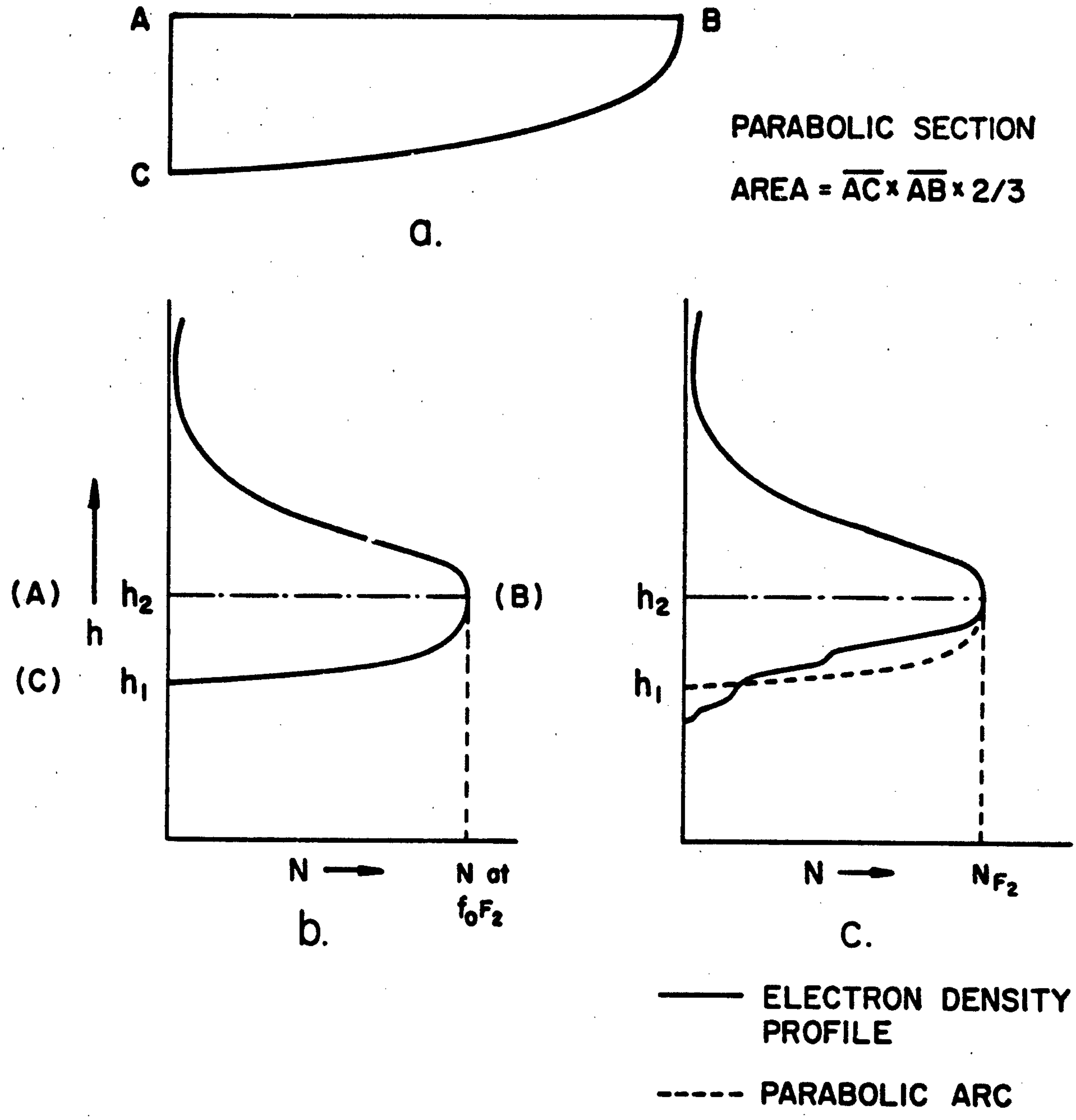

Figure 6. Parabolic bottom-side electron density profile.

time for a given day.

The above procedure implies that h_1 and h_2 are true heights, while the heights read from ionograms are apparent heights. The true heights may be determined by reading the apparent heights and plasma frequencies from the ionogram and using these values in a formula.

It has been found that the accuracy in reading $h'f_{oF_2}$ is usually poor, but the accuracy in reading f_{oF_2} is usually good. A point used in one method of calculating true heights is $0.987 \times f_{oF_2}$ ($\sin 81° \times f_{oF_2}$). This point can be read with reasonable accuracy. Using the apparent height at this point for h_2 and 95 km for h_1, a number for part of the columnar electron content was obtained which when multiplied by 1.5 gave a number for total electron content which agreed reasonably well with the resolved electron content obtained in September 1965 by our usual method using 413.25 MHz. This procedure is consistent with the true height and $(1 + r)$ procedure mentioned above, because the true height for f_{oF_2} is roughly 0.6 times the apparent height at $0.987 \times h'_{f_{oF_2}}$. The 95 km figure is used for h_1 because it has been found by rocket experiments (C. F. Sechrist, Jr., personal communication) that the lower level of the E layer is 95 km day and night. Putting all of this together gives:

$$\eta \approx [0.987\ h'_{f_oF_2} - 95] \times (f_{oF_2})^2 \times 8.27 \times 10^{12} \times a$$

where $h'_{f_{oF_2}}$ is in km and f_{oF_2} is in MHz and the factor $a \approx 1.5$ for daytime.

At times this simple procedure works quite well, but at other times the check is quite poor. By taking points for each hour of lunar observations for the days in question, application of the above procedure should give the answer to the question of resolution of the 413.25 MHz data.

4.2.3. Phase 3. Other Studies of the Data

The diurnal electron content versus time curves are being studied, especially those showing plots between midnight and sunrise. The work of others show increases of electron content during that period, while data taken at Danville since July 1961 show few instances of increase of electron content during that period. Reasons for the discrepancies between the different sets of data are being investigated.

4.3. Task C. Autocorrelation Analysis

No further work has been done on this Task.

4.4. Task D. Other Research

Between moon observations the antenna has been directed toward the ATS-1 stationary satellite in order to receive the 137.35 MHz from that satellite and measure the Faraday rotation of that signal as a function of time. The 137.35 signal was received continuously from 1120 CST May 21, 1967 to 0210 CST May 28, 1967. It had been planned to resolve the satellite data by making use of lunar data taken immediately before the antenna was directed toward the satellite and the receivers set to the satellite signal. Since the series of lunar observations ended at 2200 CST on May 16, the ATS-1 data are presently unresolved.

The period was an unusually interesting period for ionospheric observations. There was major solar flare activity on May 21 and on May 23. There was a magnetic storm which began at about 0635 CST (1235 UT)

May 25 and lasted until 2400 CST May 26. The A index for this storm was 240. It was said to be the most severe storm in a decade (according to news accounts). The most perturbed electron content record taken during the storm was from about 1000 CST to about 2100 CST, May 25. Lunar observations would have furnished no data since the moon was not visible during this time. Violent changes in electron content were observed during this time. Since there is some question about the interpretation of the data taken during this period, there will be no further discussion at this time.

The plots of relative electron content versus time for May 21, 1967 and May 23, 1967 are presented in Figures 7 and 8. On May 21 there is an increase of approximately 1.6 x 10^{16} electrons per square meter column in a period of 5 minutes, beginning at 1322 CST (1922 UT). This was accompanied by a 34 minute fadeout of the WWV signal from Ft. Collins, Colo., at 10 MHz. Prof. Paul C. Yuen of the University of Hawaii (personal communication) measured an increase of 1.9 x 10^{16} electrons per square meter column in a 3 minute period beginning at 1923 UT May 21. Since we measure Faraday rotation by rotating the antenna feed once each 4 minutes, approximately, the agreement of the time of the change and the duration of the change is very good.

The electron content curve for May 23 is more spectacular. There was a 2 B solar flare at 1809 UT (1209 CST) and a 3 B flare at 1836 UT (1236 CST). There were other 2 B flares at 1933 UT and 2047 UT. There was a short wave fadeout from 1810 to 2140 UT (1210 to 1540 CST), which corresponds to the WWV fadeout time interval in our data. The 3 B flare was an unusual one, according to Science News (June 24, 1967).

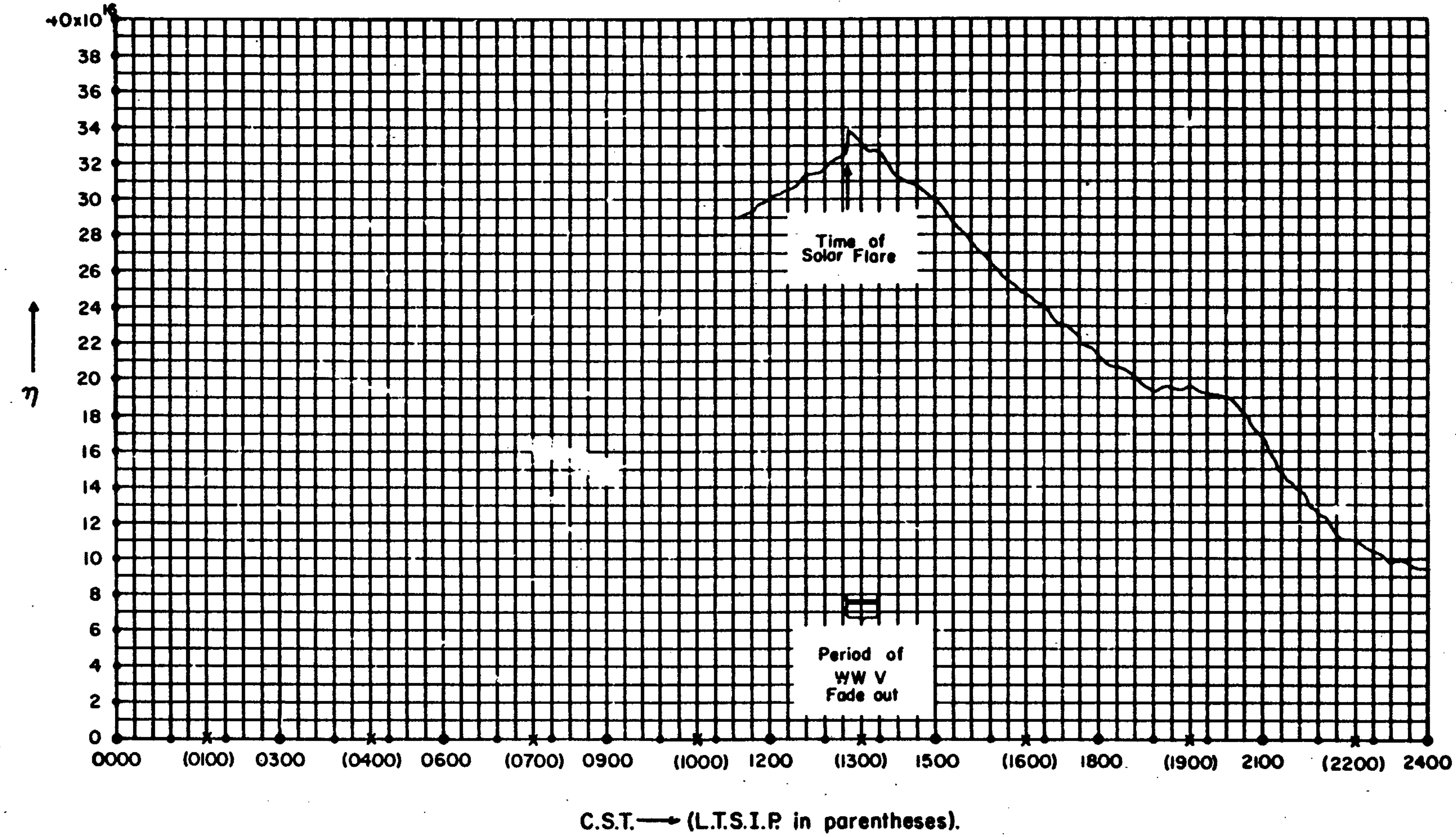

Figure 7. Relative columnar electron content, η, versus time for May 21, 1967.

η is Electrons per one square meter column

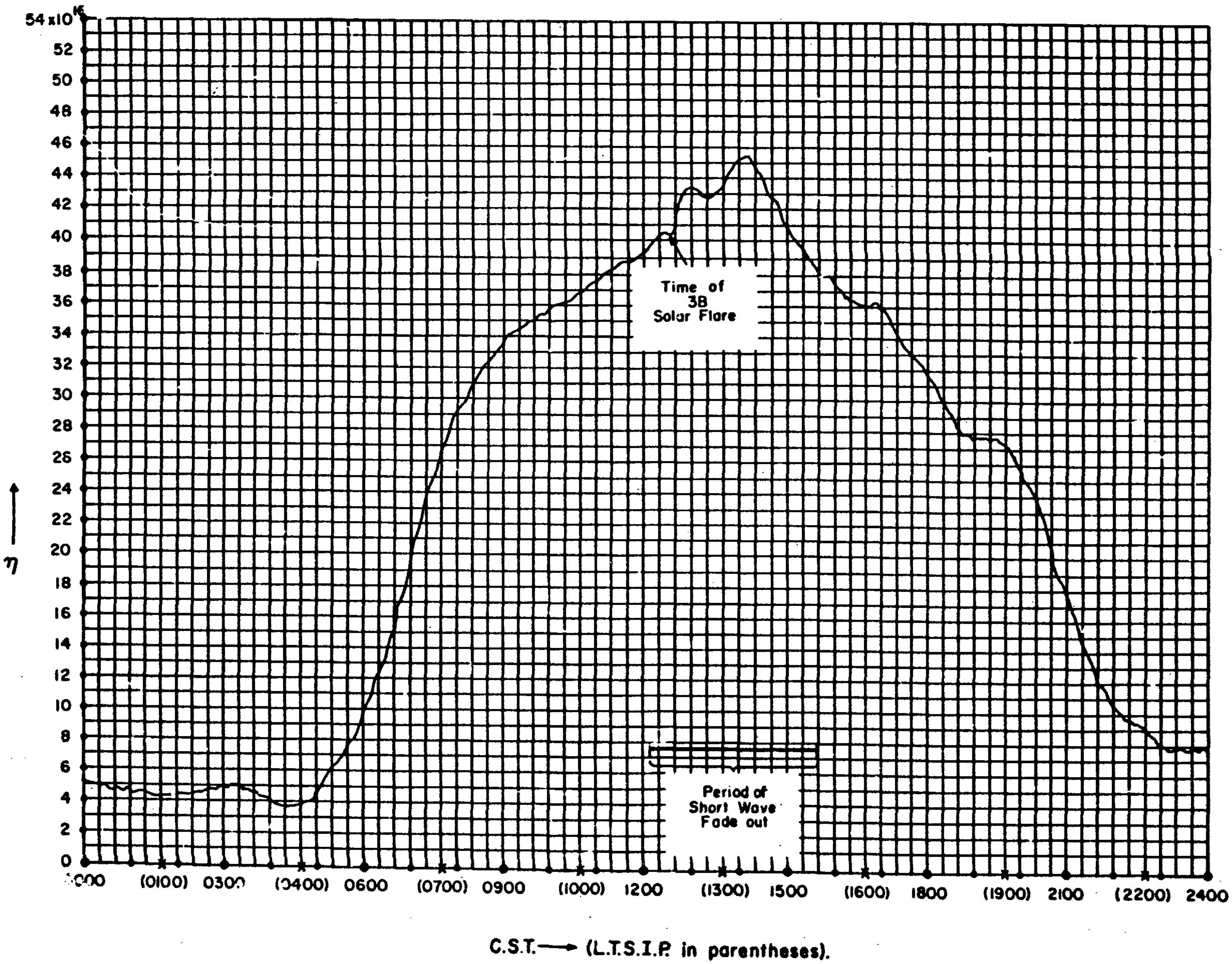

Figure 8. Relative columnar electron content, η, versus time for May 23, 1967.

η is Electrons per one square meter column

Our data shows an increase in electron content of 3.2 x 10^{16} electrons per square meter column in a 15 minute period from 1233 to 1248 CST, with an increase of 2 x 10^{16} in the period 1238 to 1244, CST.

The increase of electron content at the time of a solar flare is believed to be chiefly in the D region, due to x-rays penetrating to the lower regions of the ionosphere. According to the M.S. thesis by J. W. Rokus (Seventh Quarterly Progress Report, Appendix B), a flare would have to be unusually large to produce the kind of effect observed on May 23.

The ATS-1 data for May 21-28 and the outstanding event of that period are to be studied further.

REFERENCES

(1) "Principles of Phase Control," General Electric Sillicon Controlled Rectifier Manual, Edition Number 3, General Electric Rectifier Components Department, Auburn, New York, 1964.

(2) 13th Quarterly Progress Report, Contract No. DA-36-039-AMC 03703(E), 1967.

5. CONCLUSIONS

Moon-reflected signals were received at 150.6 MHz on 35 days for approximately 330 hours of usable recorded signals, and at 413.25 MHz on 35 days for approximately 64 hours of operation. There were several relatively small magnetic storms that were in progress during the lunar observations. The data have not been analyzed; therefore, no statement can be made about electron content irregularities at those times.

The servo amplifiers for both the azimuth and elevation antenna drives have been replaced with solid state amplifiers which use SCR's to furnish the motor drives. Circuit diagrams for the latest versions of these amplifiers are presented. These amplifiers are working quite well so far.

A simplified method for getting approximate total electron content using ionograms shows promise as a quick method for resolving any n x 180° ambiguity in the 413.25 MHz data.

Signals from the ATS-1 geostationary satellite were received continuously from 1120 CST May 21 to 0210 CST May 28. There were marked changes in electron content over six minute periods at times of major solar flares on May 21 and May 23. A change of 1.6×10^{16} electrons per square meter column was measured during a five minute period. At the same time Prof. Yuen in Hawaii measured a change of 1.9×10^{16} in a three minute period. There was a 3 B solar flare at 1236 CST on May 23. At the time of this flare there was a change of 3.2×10^{16} electrons per square meter column in a 15 minute period.

There was a major magnetic storm May 25-27. There were violent fluctuations of electron content during this time. These results are not included in this report because further study is needed before a preliminary report is made.

6. PLANS FOR THE NEXT INTERVAL

Observations on 150.6 MHz and 413.25 MHz are being planned for July 5-15, August 3-15 and September 1-14.

Between July 15 and August 3 it is planned to modify the gear ratio in the polarization rotation gear assembly so that the antenna feed will rotate once each 6 minutes or 0.1 of an hour. This is being done to facilitate the data read-out and to speed up the data processing procedure.

It is planned to receive signals from the ATS-1 geostationary satellite between the moon observation times.

It is expected that the work on Volume V of the Atlas of Lunar Data for 1966 data will have been completed by the end of the next quarter.

The work on topside to bottomside ratio and seasonal averages will continue.

7. PERSONNEL

Name	Title	Percent of Time Charged to Project
Harold D. Webb	Professor, Project Director	50%
David Cowling	Graduate Assistant	50%
Donald Jeanblanc	Graduate Student Assistant	20%

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13. ABSTRACT

Moon reflected signals were received at 150.6 MHz and 413.25 MHz on 35 days for 330 and 64 hours of operation, respectively. The operational times are summarized in tabular and in graphical form.

Solid state servo amplifiers using SCR's are in operation for both azimuthal and elevation control. Circuit diagrams and brief descriptions of operation are given.

Uncertainties in some of the 413.25 MHz data for 1966 are being resolved using ionograms. Some topside to bottomside ratios for 1965 data have been calculated.

Signals from ATS-1 were recorded from 1120 CST May 21 to 0210 CST May 28. This period included several major solar flares and a severe magnetic storm May 25-27. The electron content data for May 21 and May 23 are presented. At the time of the flare on May 21 there was an increase of 1.6×10^{16} electrons per square meter in 5 minutes. On May 23, at the time of the flare there was an increase of 3.2×10^{16} electrons per square meter in 15 minutes.

Data showing unusual effects during the magnetic storm May 25 are withheld, pending further study.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Moon-Reflected Signals						
Resolving n x 180° Amgibuity						
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Topside to Bottomside Ratio						
Solar Activity						
Electron Content						
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